Effects of Spring Runoff on the North Saskatchewan River Edmonton-1982

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SUMMARY

A study was undertaken to identify possible causes of the taste and odor problems associated with spring runoff in Edmonton drinking water. Results showed a measureable change in water quality between the two water treatment plants. The North Saskatchewan River at the E.L. Smith water treatment plant upstream showed little change in measured parameters over the runoff period. At Rossdale, downstream of a number of major storm sewers, the river showed considerable change in water quality. These changes, in major ions, metals and organics, were coincident with occasions when runoff was discharging to the river via the storm sewers.

The chemistry of, and flow, from the storm sewer discharge was extremely variable but predictable on a diurnal pattern. A preliminary mass balance suggests that the storm sewers are the major contributor to changes in water quality during spring runoff.

Introduction

An annual phenomenon in the City of Edmonton has been the taste and odor of the drinking water during the spring. This has been related to the spring runoff and two hypotheses have been proposed to explain the event.

i) the quality is a result of spring runoff and organic components occurring naturally in the river's watershed; and

ii) more specifically, it derives from Edmonton urban runoff entering the river from the city storm sewers upstream of the Rossdale water treatment plant.

The City of Edmonton has two water treatment plants (Fig. 1). E. L. Smith, a newer facility, was completed in 1976 and is located upstream of the city. There are essentially no point source discharges above the plant before Devon, at which point the river water may be considered natural. The second older plant is located at Rossdale and is downstream of a considerable number of storm sewers draining approximately 15,000 hectares of the city (Table 1).

A sampling programme was designed:

i) to compare the river at the two Water Treatment Plant intakes and identify any change in chemical water quality, particularly with reference to Alberta surface water quality objectives,

ii) to identify and characterize the quality of the storm water discharge; and

iii) to relate any changes in river quality to the storm sewer discharges.

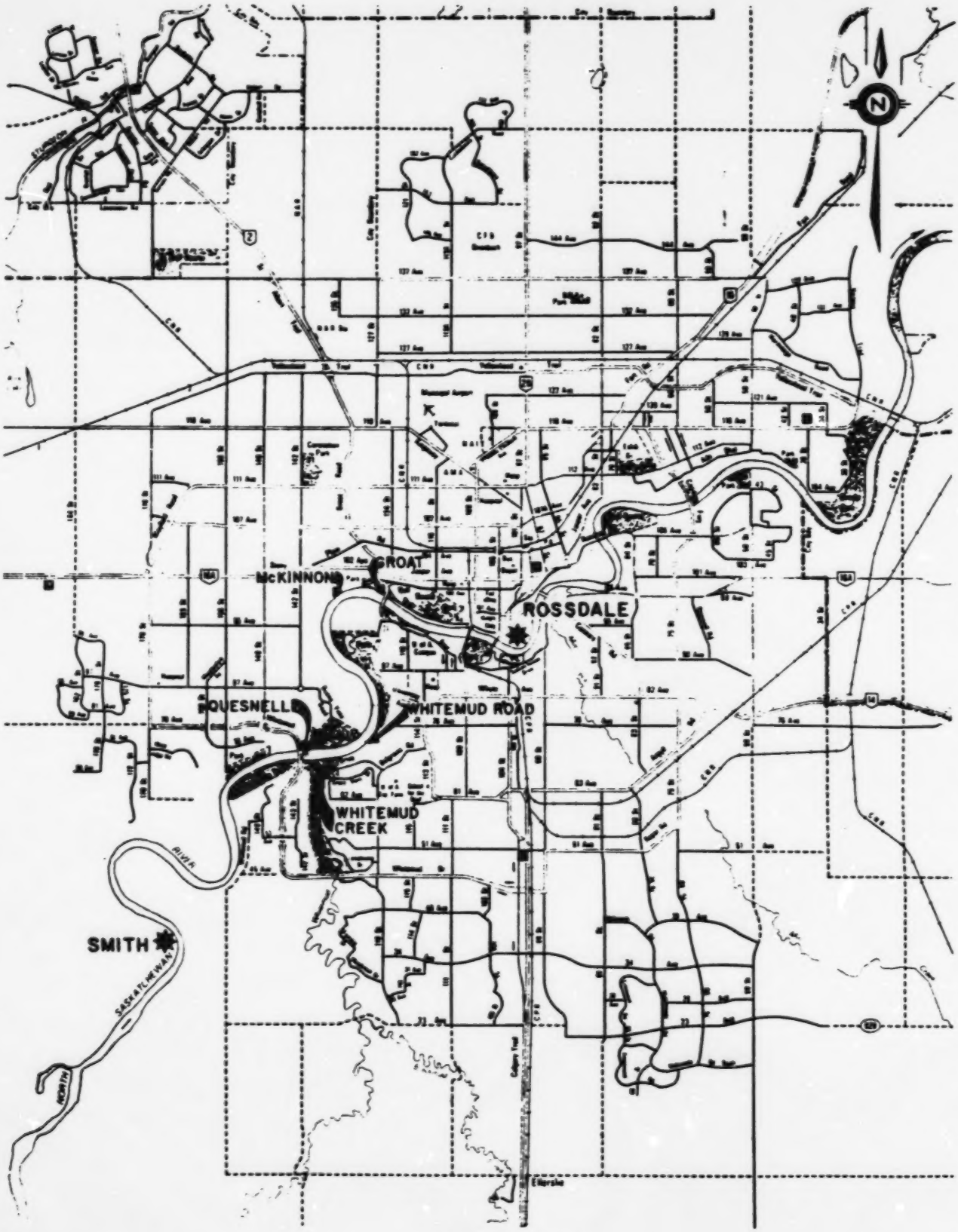

Figure 1. Storm sewer (⟶) and river sampling site (✱) locations.

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TABLE 1

Separate Storm Sewers Discharging to the North Saskatchewan River Upstream of Rossdale Water Treatment Plant

Sewer	Drainage Area Hectares	Industrial Portion %
Lessard	1260	0
Wolf Willow	1260	0
Terwilligar Park	3821	18
Whitemud Creek	1656	0
Ft. Edm. Park	261	0
Whitemud Road	486	0
Quesnell Bridge N.	2987	24
Laurier Park	168	0
Buena Vista	167	0
McKenzie Ravine	319	0
McKinnon Ravine	818	15
Emily Murphy Park	80	0
Groat Road N.	1740	25

(from: Final Report on Impact of Sewer System Discharges on Potable Water Quality in Edmonton. Edmonton Water and Sanitation, 1980.)

Methods

The sampling schedule was designed to coincide with the spring runoff event. Although accumulated snowfall (Fig. 2) indicated that the first few days were missed, visual observation of the storm sewer outfalls showed little apparent discharge to the river. This decrease in snow depth was likely due to consolidation and evaporation.

Simple grab samples were taken at the storm sewer outfalls, and river samples were obtained from the water treatment plant (W.T.P.) intakes and assumed to be representative of the raw water. It was not possible during this time to take samples directly from the river because of unsafe ice conditions. Samples were taken on a daily basis as far as was possible.

From Table 1 there are twelve storm sewers, together with Whitemud Creek, draining urban spring runoff to the North Saskatchewan River upstream of Rossdale W.T.P.. Of these only Groat Road North, Quesnell Bridge North and Whitemud Road proved continually accessible for sampling. These three however, drain over 30% of the city discharges upstream of Rossdale W.T.P. Occasional samples were also obtained from Whitemud Creek.

Results

i) Comparison of North Saskatchewan River

The first objective of this study was the identification of any change in water quality in the North Saskatchewan River between the E. L. Smith and Rossdale W.T.P.'s. Over a twenty-five day period, twenty-nine samples were collected and fifty-five chemical parameters analyzed. With the large volume of data produced, multivariate analyses techniques were used for examining the information. This technique has

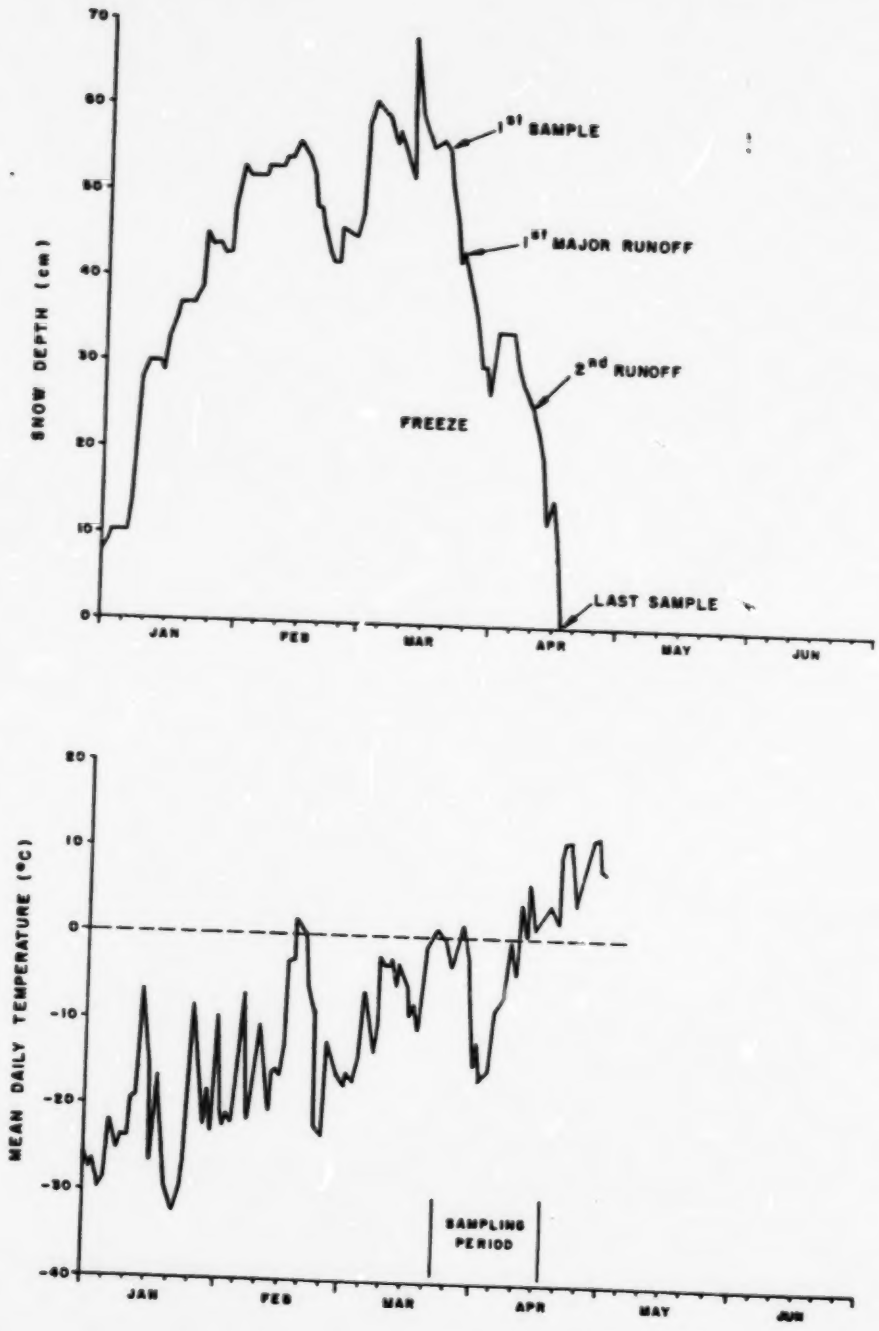

Figure 2. Spring Runoff (1982) as shown by decreasing snow depth and ambient temperature.

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two advantages, first it clearly demonstrates and quantifies the existence of differences between sets of samples, and second, it identifies those parameters responsible for the observed differences for further examination.

The method used was Principal Components Analysis (PCA) from the Clustan 1C package (Wishart, 1975). The chemical parameter groups of concern were: selected on the basis of their characterization of river quality and the type of materials present in urban runoff water. The three main parameters of concern were: organic chemicals, particularly phenols, which are a taste and odor causing group, and oils and grease; metals; and major ions particularly sodium and chloride from salt use in the winter period (a complete parameter list is presented in Appendix 1).

Two data assessments were undertaken, one for the metal parameters and a second for the major ions and organic parameters. Figure 3 shows the results of cluster analysis and the PCA of the metal parameters from Rossdale and E. L. Smith. The cluster diagram (Fig. 3B) shows: firstly, a greater variation in the metal chemistry, of the river at Rossdale as indicated by the larger area enclosed by the solid line. Secondly, a considerable difference in metal chemistry at the two sites, the extent of similarity being indicated by the overlap areas within the boundary lines (shaded); and finally, presuming the E. L. Smith samples to have represented a natural range of metal chemistry only one sample from Rossdale (March 28) which lay within this range. This indicates a major difference in metal chemistry of the North Saskatchewan River between E. L. Smith and Rossdale. Of the twenty-two metals examined the following account for almost 55% of the variance in metal chemistry:

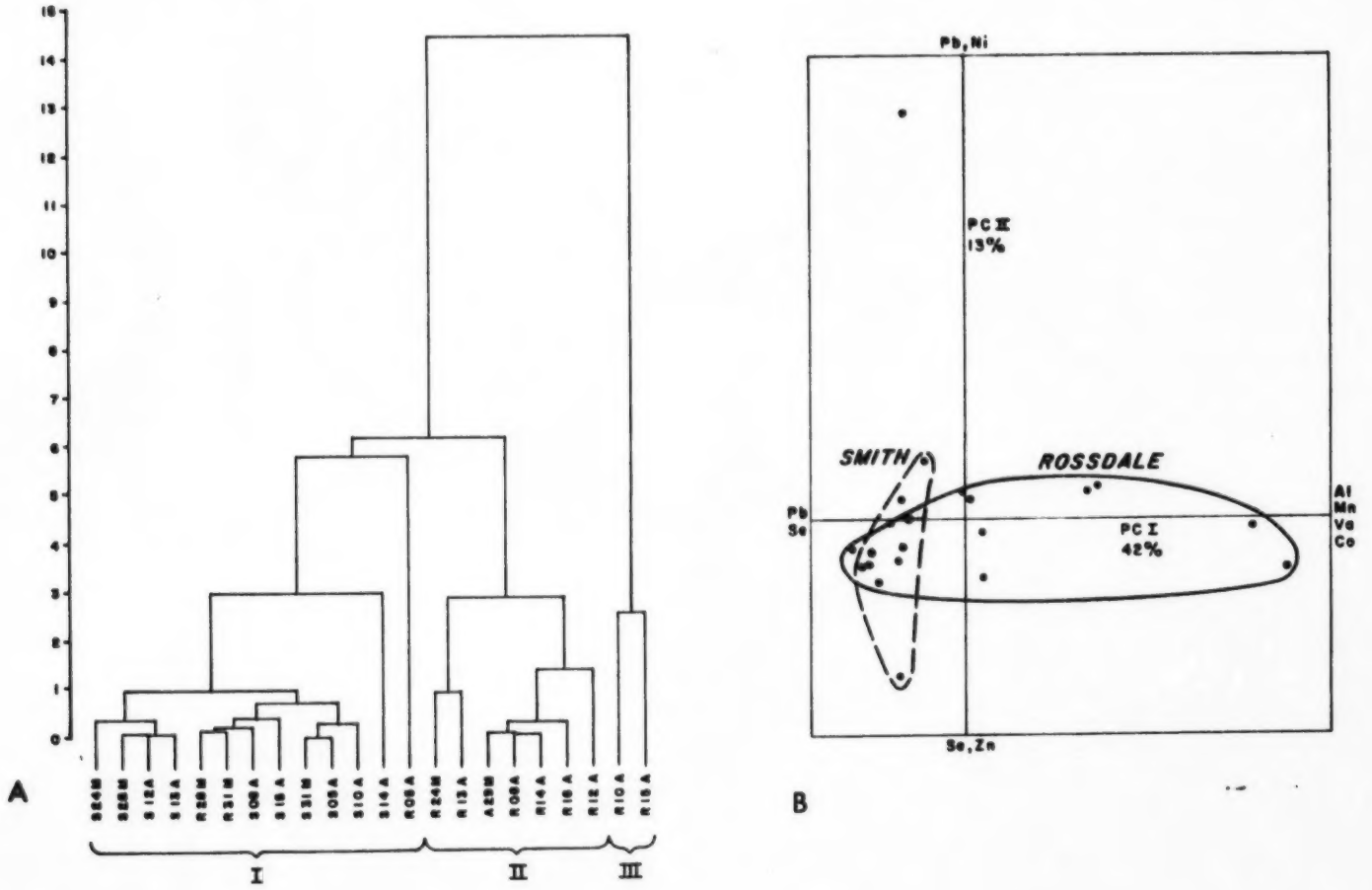

Figure 3. River water - Metals.

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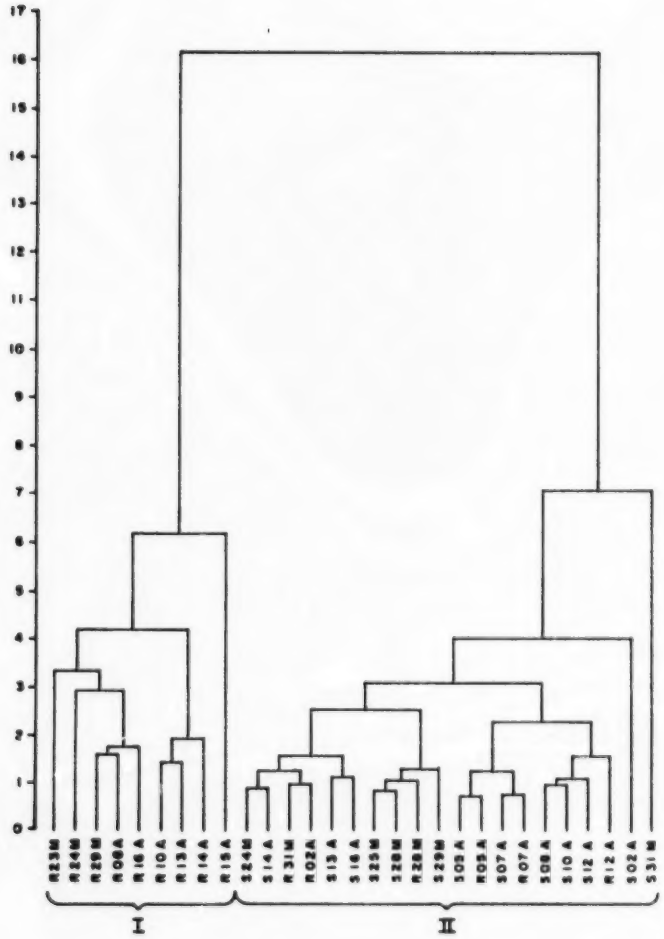

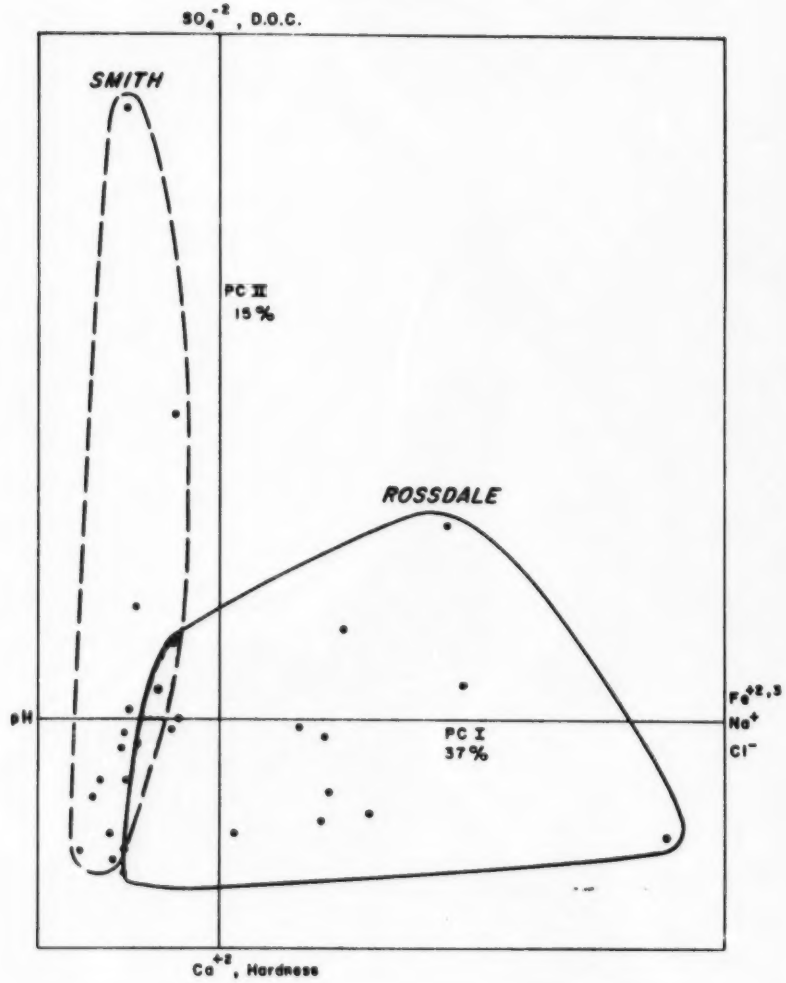

Figure 4. River water - Organic compounds and major ions.

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aluminum, manganese, vanadium, cobalt, lead, selenium, nickel and zinc.

Analyses of organic and major ion parameters showed two large groups (Fig. 4 dendrogram). Group I consisted of Rossdale samples only. Group II of all the Smith samples together with six Rossdale samples.

The components plot (Fig. 4) showed an almost complete separation of the Rossdale and Smith samples as shown by the boundary lines for the two sites. The main parameters explaining the sample variance were iron, sodium, chloride and pH. From these results, changes in five metal parameters, two major ions and total carbon, were compared over the sampling period (Fig. 5). These were selected as being the most significant in explaining the change in water quality of the river between the two sites. The following observations were made in the behaviour of each parameter (Fig. 5):

a) In all cases the values were higher at Rossdale than at E. L. Smith.

b) There was a similar pattern to the behaviour of these parameters at the two sites. At the beginning of the study period the concentrations were higher at Rossdale, for most parameters considerably higher. This was followed by a period when concentrations declined to levels similar to those at Smith. Finally there was a period when the concentrations at Rossdale increased once again.

c) This response was related to temperature; when air temperatures increased to close to or above 0°C then the difference in concentration of the parameters between the two sites increased.

d) By the end of the sampling period concentrations of these parameters were declining. The decline was associated with the latter part of the runoff when the discharge from the storm sewers was reduced.

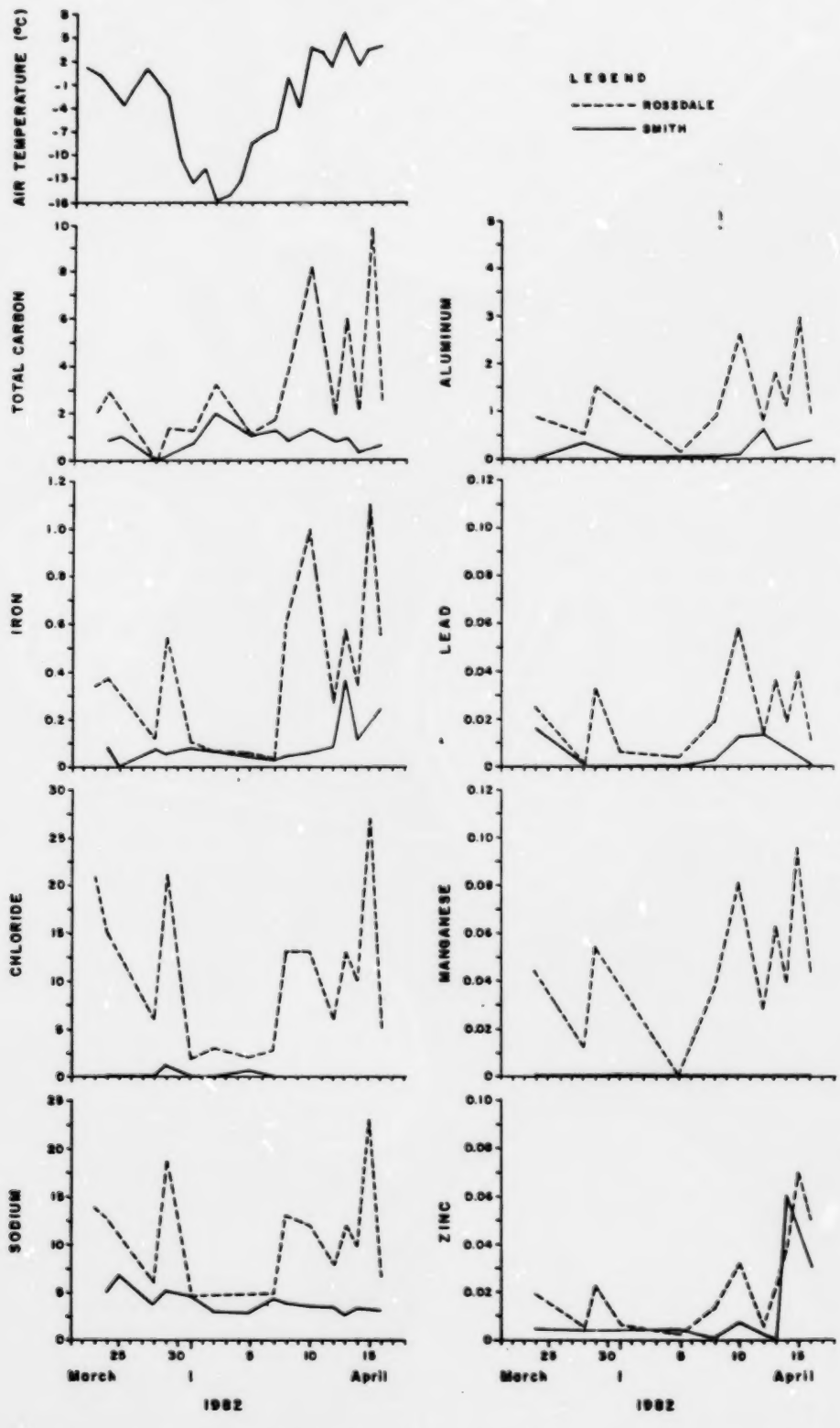

Figure 5. Selected chemical parameters (mg/L) for raw water supply from the North Saskatchewan River.

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From these observations, it is concluded that the change in water quality in the North Saskatchewan River between E. L. Smith and Rossdale is directly related to temperature and occurs at the time the storm sewers are discharging spring runoff water to the river between the sampling stations. It is suggested, therefore, that the storm sewers are at least partially responsible for this change in water quality and that on occasion Alberta Surface Water Quality objectives at Rossdale were not met.

As an indication of the impact on the North Saskatchewan River during the spring runoff period, data from the two sites were compared with Alberta Surface Water Quality Objectives (Alberta Environment, 1977). Mean values, for analyzed parameters which have established limits, are shown together with the range and the objective value (Table 2).

For only one parameter, iron, did the mean value exceed the objective concentrations at Rossdale, and none exceeded the objectives at Smith. The other parameters, lead, copper, manganese, zinc and phenolics, on occasion exceeded the objective values at Rossdale but not at Smith. From Table 2 it is clear, however, that there are considerable inputs of lead to the river between Smith and Rossdale as well as some other metals (copper, iron, manganese and zinc). Both iron and manganese can cause taste and odor in drinking water but not at these levels. Another major contributor to taste and odor in drinking water is phenols. These were never detected at Smith but were found at Rossdale on four occasions. On two of these occasions, the concentrations exceeded surface water objectives.

TABLE 2

Average Concentrations and Ranges of

Selected Chemical Parameters in the North Saskatchewan River.

Chemical Substances Related to Health

	A.S.W.O.	ROSSDALE		SMITH	
		conc'n	range	conc'n	range
Arsenic	0.01 mg/L	0.001	0-0.0051	0.0066	0-0.0020
Cadmium	0.01 mg/L	0.001	0-0.002	0.001	0.001
Chromium	0.05 mg/L	0.006	0-0.009	0.004	0-0.007
Lead	0.05 mg/L	0.022	0-0.058	0.013	0-0.016
Mercury	0.0001 mg/L	0.0001	0.0001	0.0001	0.0001
Selenium	0.01 mg/L	0.00001	0-0.00003	0.00002	0-0.00009

Substances Related to Aesthetic and Other Conditons

	A.S.W.O.	ROSSDALE		SMITH	
		conc'n	range	conc'n	range
Chloride	N.A.	11	2-27	1	0-3
Copper	0.02	0.008	0-0.055	0.001	0-.002
Iron	0.3	0.41	.04-1.11	0.10	0-.37
Manganese	0.05	0.046	0-0.094	0.008	0-.012
Zinc	0.05	0.024	.002-0.071	0.012	0-.060
Phenolics	0.005	0.002	0-0.006	0.002	0.002

ii) Storm Sewer Characterization

The chemistry of the spring runoff was examined to determine quantitatively the role of storm sewer effluent in causing the described changes in river water quality. The parameters shown to be significant in the river (Fig. 5) are presented for the two major storm sewers which were sampled most frequently (Fig. 6).

Two general points are noteworthy regarding storm sewer effluent quality. First, concentrations are much higher in the effluent than the river, an order of magnitude in most cases (Fig. 6). Second, there was a similarity in the quality of effluent from the storm sewers sampled during the runoff period.

There was very little difference in effluent quality between Quesnell and Groat Road storm sewers. The Whitemud Creek and the Whitemud Road storm sewer were sampled less frequently. PCA confirmed the similarity in effluent quality (Fig. 7, 8) for the sewers and indicates more variation in a single sewer through time than between sewers at a specific time. The large variation in effluent quality through time is perhaps, in part, a result of the particular type of runoff for the sampled year.

A comparison of those parameters presented for the North Saskatchewan River in Table 2 is shown in Table 3. The average concentration and range is shown for the parameters for each of the two runoff periods from the Groat Road North and Quesnell Bridge North sewers locations, those sewers for which the most data were available.

With the exception of mercury, which was not detected in the runoff, concentrations of all these parameters (Table 3) were much higher, and in most cases an order of magnitude higher, than in the river. These data also show the similarity in runoff for these two

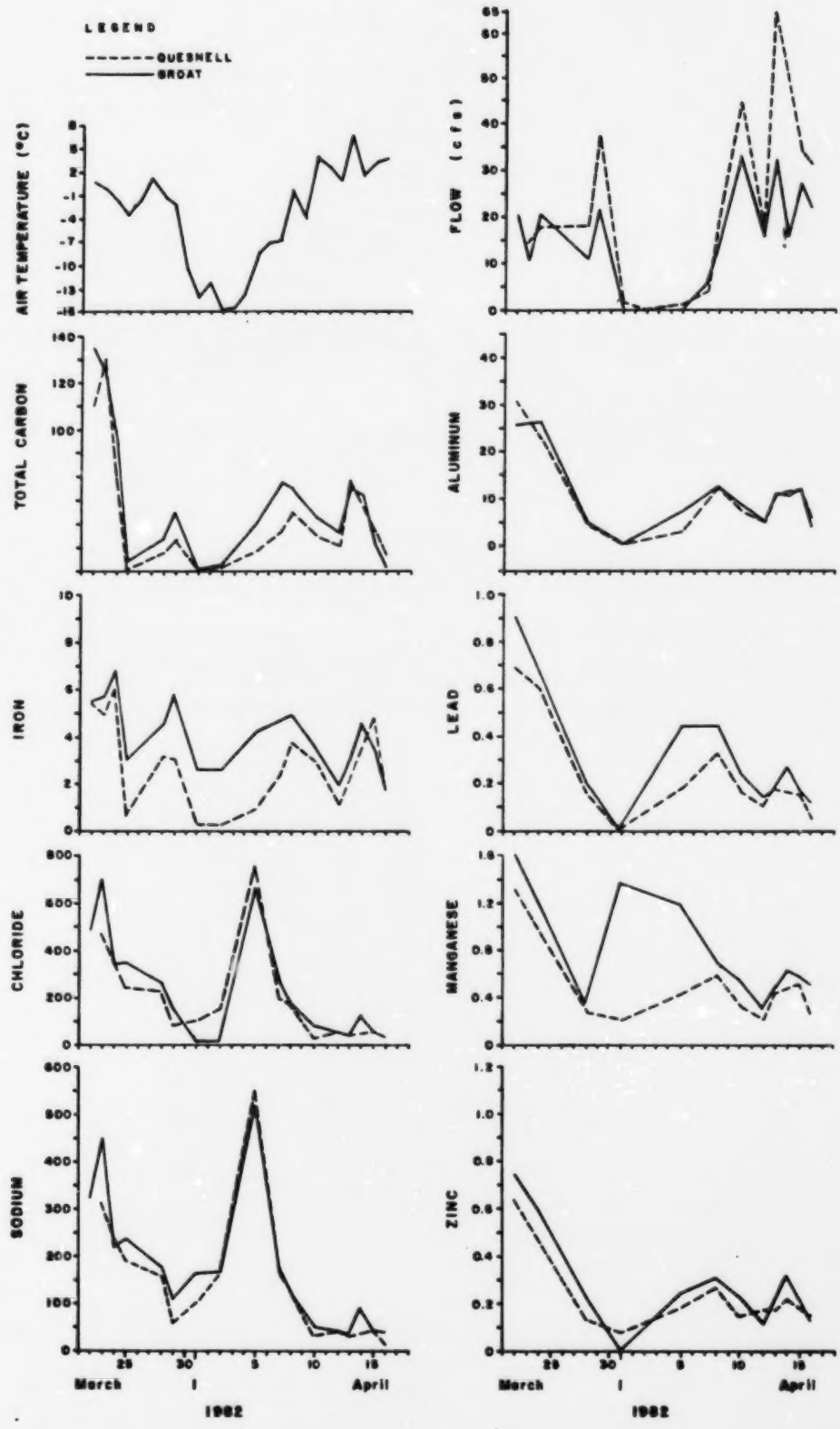

Figure 6. Selected chemical parameters (mg/L) for two storm sewers.

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TABLE 3

Concentrations (mg.L) of selected parameters from two storm sewers.

	March 23 - 30, 1982				April 6 - 16, 1982			
Storm Sewer	Groat		Quesnell		Groat		Quesnell	
	mean	range	mean	range	mean	range	mean	range
Arsenic	0.0082	(0.0051 - 0.0114)	0.0092	(0.0044 - 0.0135)	0.0061	(0.0027 - 0.0118)	0.0053	(0.0014 - 0.0117)
Cadmium	0.010	(0.004 - 0.016)	0.007	(0.002 - 0.011)	0.003	(0.002 - 0.004)	0.003	(0 - 0.005)
Chromium	0.055	(0.018 - 0.075)	0.103	(0.021 - 0.216)	0.029	(0.013 - 0.041)	0.044	(0.025 - 0.099)
Lead	0.606	(0.210 - 0.906)	0.504	(0.212 - 0.694)	0.223	(0.115 - 0.440)	0.173	(0.062 - 0.330)
Mercury	< 0.0001		< 0.0001		< 0.0001		< 0.0001	
Selenium	0.0004	(0 - 0.0010)	0.0003	(0 - 0.0009)	0.0004	(0 - 0.0016)	0.0002	(0 - 0.0006)
Chloride	346	(170 - 600)	105	(24 - 175)	92	(32 - 240)	69	(41 - 85)
Copper	0.101	(0.05 - 0.145)	0.080	(0.020 - 0.132)	0.048	(0.020 - 0.076)	0.030	(0.016 - 0.031)
Iron	5.25	(2.98 - 6.88)	1.86	(0.10 - 3.46)	3.45	(1.68 - 4.87)	2.42	(1.54 - 4.23)
Manganese	1.04	(0.34 - 1.58)	0.91	(0.42 - 1.31)	0.48	(0.30 - 0.70)	0.40	(0.25 - 0.58)
Zinc	0.501	(0.238 - 0.739)	0.423	(0.158 - 0.640)	0.217	(0.118 - 0.311)	0.194	(0.149 - 0.272)
Phenolics	0.034	(0.014 - 0.067)	0.028	(0.009 - 0.051)	0.035	(0.020 - 0.055)	0.031	(0.018 - 0.036)

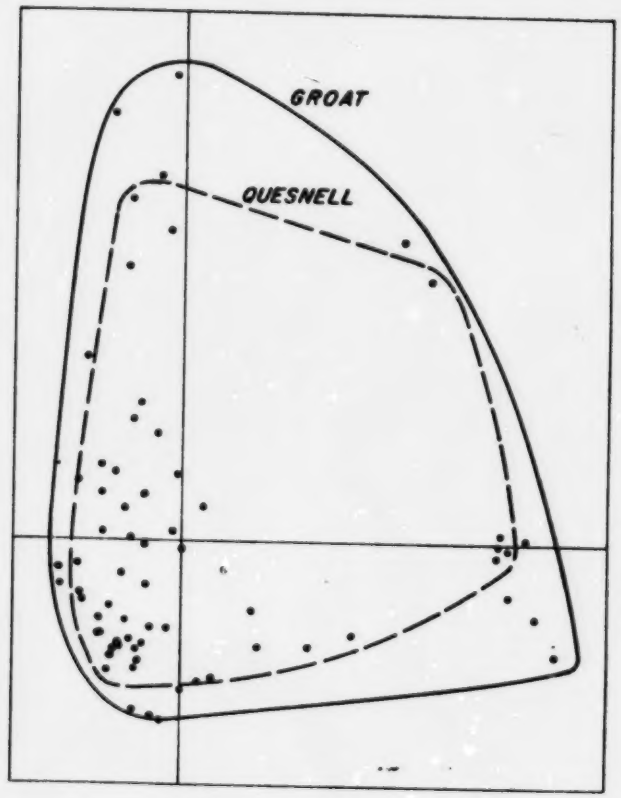

Figure 7. River water - Organic compounds and major ions.

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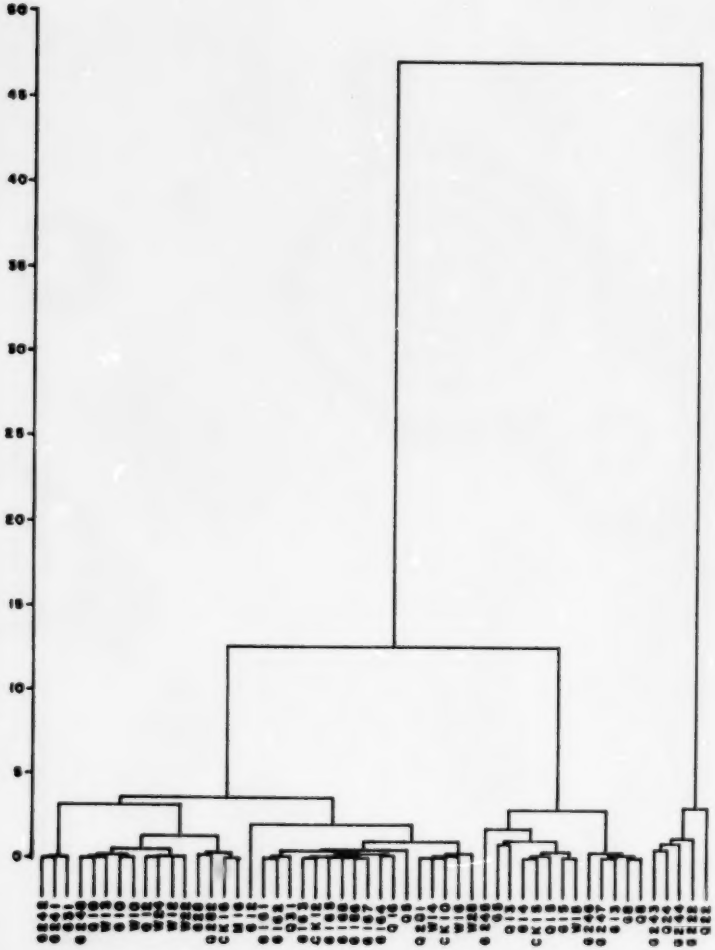

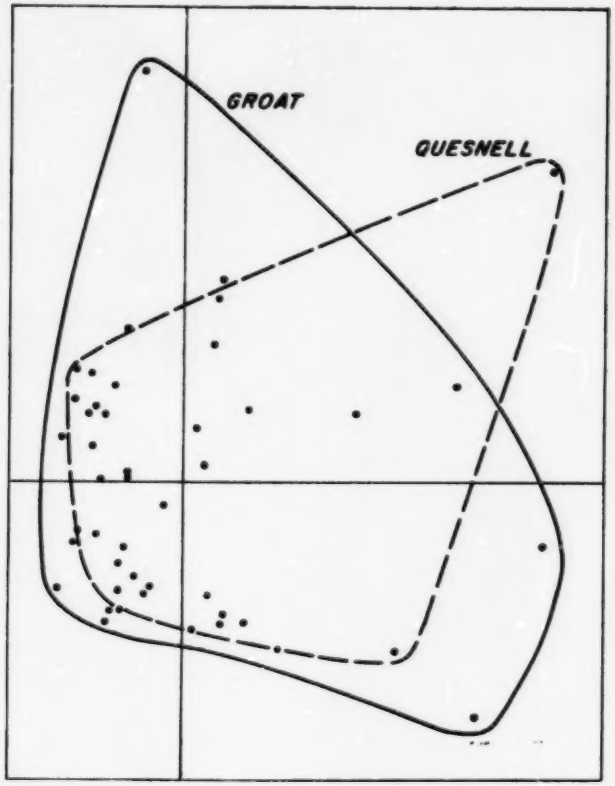

Figure 8. River water - Metals .

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storm sewers.

Because taste and odors have been attributed to organic compounds, organic scans were done on two occasions on both the storm sewers and the river (Table 4).

On the one occasion, organic compounds were detected in sufficient quantities for analysis in the Groat Road storm sewer. The following compounds were the major components: methyl ethyl and dimethyl ethyl benzenes, napthalene, methyl and dimethyl napthalenes and straight and branched alkanes and alkenes.

TABLE 4

Organics Detected in River and Storm Sewers

Site	25.3.82	10.4.82
Groat Rd. S.S.	850 µ g.L	Trace (< 0.1 mg.L)
Quesnell Br. S.S.	1.5 µ g.L	Trace (< 0.1 mg.L)
Whitemud Rd. S.S.	-	Trace (< 0.1 mg.L)
Whitemud Ck.	-	Trace (< 0.1 mg.L)
E.L. Smith (river)	Trace (< 0.1 µ g.L)	0 (< 0.1 mg.L)
Rossdale (river)	Trace (< 0.1 µ g.L)	Trace (< 0.1 mg.L)

There were three phases to the 1982 runoff. Figure 2 shows an initial runoff period from March 10th to March 30th accompanied by peak storm sewer flow from March 23rd to March 30th. A cold period followed from March 31st to April 3rd during which there was little flow from the storm sewers. With warming temperatures, runoff began again April 6th and was completed by April 16th. The storm sewers began major flow from April 8th to April 16th.

These phases of runoff coincided with changes in the effluent quality of the storm sewers. The initial runoff had high concentrations which gradually declined as the runoff period continued. There were two of these events corresponding to the two runoff periods (Fig. 6). This also appeared to correspond well with the changes in river quality for those observed parameters between Smith and Rossdale (Fig. 5). However, a better indication of the relative role of the effluent was sought by estimating the daily loading of these parameters from the storm sewers.

iii) Mass Input from Storm Sewers

To quantify the role of storm sewer inputs in causing the change in river water quality between Smith and Rossdale, a mass balance approach was deemed most suitable. Daily change in mass in the river between the two sites was compared with estimated daily loadings to the river from storm sewer runoff for conservative parameters.

An estimation of the total daily loading was derived from two diurnal studies on the Groat Road storm sewer. From instantaneous flow and concentration taken at two-hour intervals, a diurnal mass loading was determined (Fig. 9). The two studies were done at the beginning (March 24th) and end (April 16th) of the runoff and both showed peak flow and loading to occur between 14.00 and 16.00 hours. The major differences were the lower peak concentrations at the end of the runoff period (Fig. 9) and the lower total daily loadings towards the end of the runoff (Table 5). It is clear that large masses of material were discharged to the river during this period from the storm sewers (Table 5). From the similarity between the four sewers examined (Section ii, Fig. 7 and 8) the data from Groat Road Storm Sewer were considered representative of Edmonton spring runoff and used to calcu-

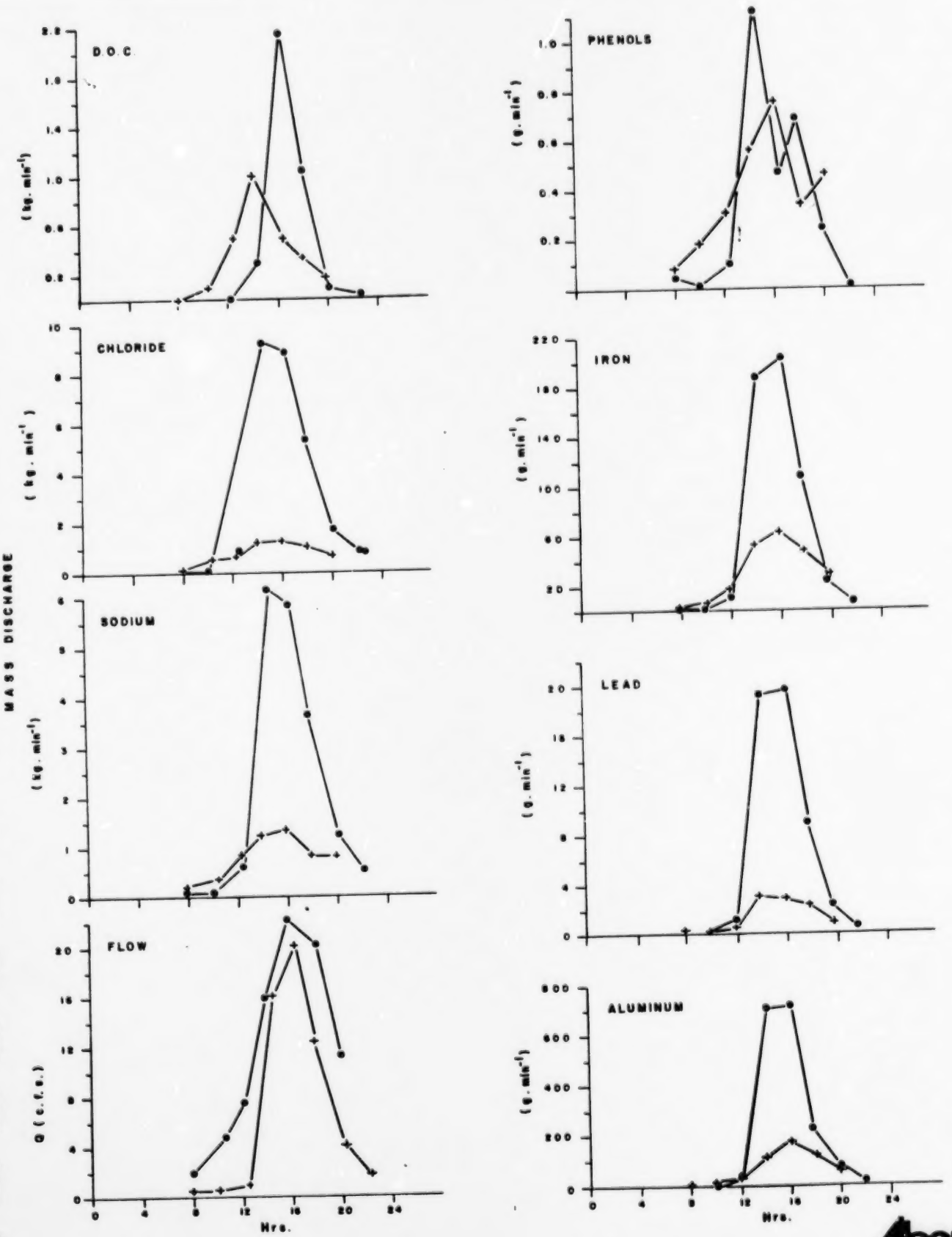

Figure 9. Diurnal variations on two occasions for selected parameters at Groat Rd. S.S.

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late a total input from Edmonton storm sewers discharging between E. L. Smith and Rossdale by using an areal extropolation calculated from planimetry.

To determine daily loadings over the runoff period when single daily samples were taken, the loading represented by the sampling time was extrapolated from the diurnal studies. All storm sewers were sampled between 14:00 and 16:00 hours. From the two diurnal studies this was shown to represent approximately 30% of the total daily load (Fig. 4) and estimated total daily loadings were based on this assumption.

To assess the change in mass of sodium and chloride in the river between Smith and Rossdale two assumption were made. First, that over a 24 hour period a diurnal concentration pattern similar to the storm sewers ocurred and that the sampled concentrations for each parameter at Rossdale (Fig. 5) represented the maximum difference between the two sites. This accounted for 30% of the total daily mass loading between E. L. Smith and Rossdale. Second, that the river at both water treatment plants was uniformly mixed. This is likely to be true at E. L. Smith, there is some question of the mixing regime at Rossdale that requires further investigation.

Given the other potentially large errors in this type of calculation, these approximations are considered acceptable. Any errors in either analysis or assumption have to be reviewed in light of the extremely large flows in the river and their effect on mass balance calculations.

From this, comparisons were made between calculated daily mass input to the river between E. L. Smith and Rossdale and the contribution from the storm sewers. These data are presented in Figure 10, which

compares estimated inputs for the two conservative parameters for each sampling date. While this has to be considered a qualitative assessment, it does demonstrate the potential role of the storm sewers in effecting water quality during the runoff period. It is interesting to note that the storm sewers appeared to account for a greater portion of the change in mass during the early part of the runoff compared with the end (Fig. 10) . Observations showed the snow dumps to be melting during the later period which could have contributed to the change in mass in the river at that time.

TABLE 5

Calculated Loading for Two 24 Hour Periods for Selected Parameters to the North Saskatchewan River during Spring Runoff 1982 (kilograms)

	Loading from Groat Rd S.S.		Total Loading from S.S's Upstream of Rossdale	
	24.3.82	16.4.82	24.3.82	16.4.82
Sodium	2155	660	24998	7656
Chloride	3233	633	37503	7343
Iron	65	26	754	302
Lead	6.3	1.3	73	15
Aluminum	216	65	2506	754
Phenols	0.3	0.3	3.5	3.5
DOC	444	322	5150	3735

It is clear from these results that input from the storm sewers does play a significant role, particularly during the early part of

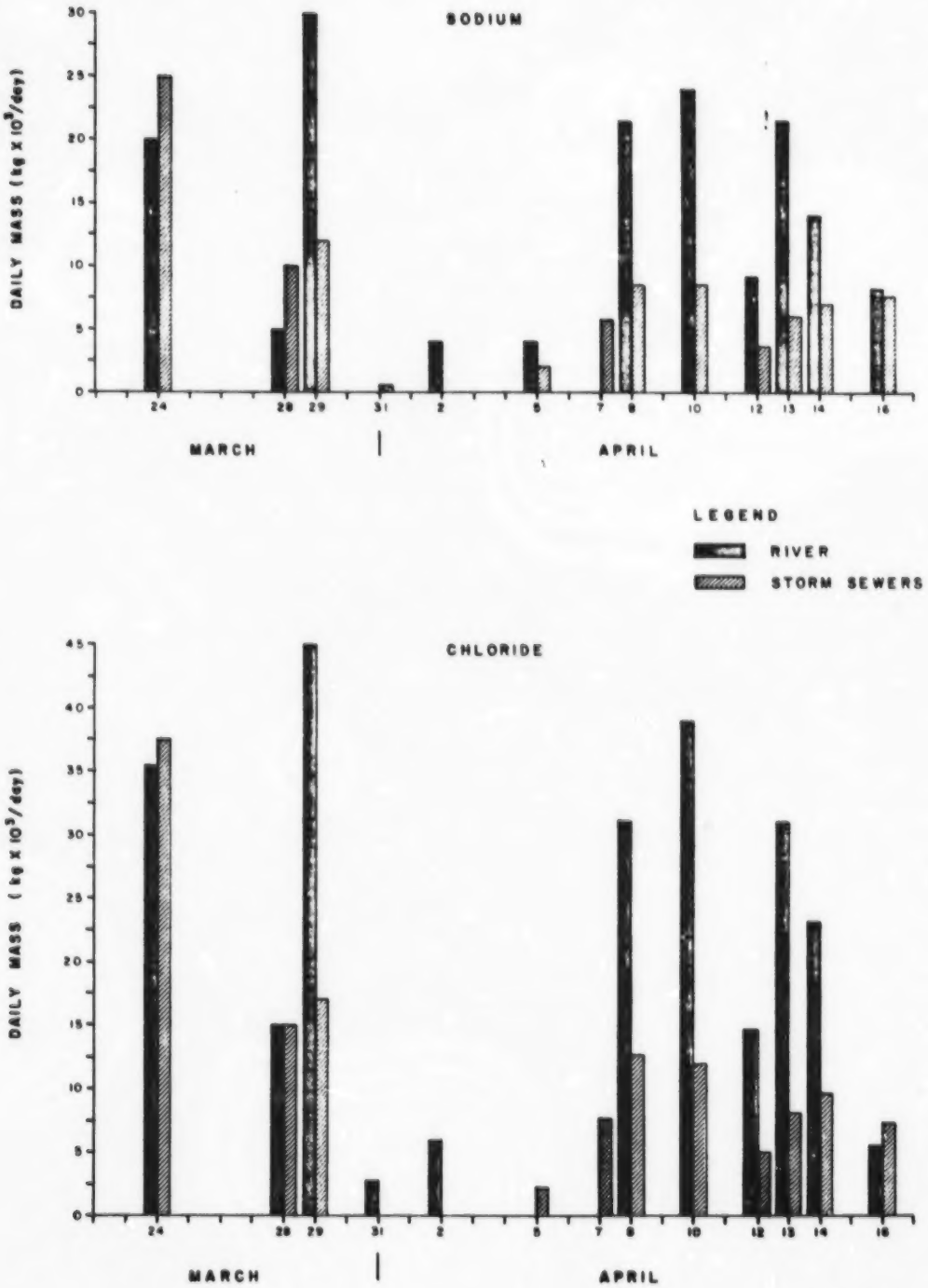

Figure 10. Comparison of masses of conservative parameters.

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runoff, in contributing to the change in water quality in the North Saskachewan River during spring runoff.

Conclusions

1) There is an impairment of water quality in the North Saskatchewan River during spring runoff which includes high levels of sodium, chloride, some metals and organics including those that can cause taste and odor.

2) The phenomenon is related to temperature and runoff.

3) The compounds that appear in the river are present in the storm sewer effluent.

APPENDIX 1: CHEMICAL ANALYSIS PARAMETER LIST -
North Saskatchewan River Storm Sewer Survey

MAJOR IONS & MAJOR ION RELATED PARAMETERS

CONDUCTIVITY	CHLORIDE	ALKALINITY
CALCIUM	SULPHATE	BICARBONATE
MAGNESIUM	SILICA	CARBONATE
HARDNESS TOTAL	FLUORIDE	DISSOLVED INORGANIC CARBON
POTASSIUM	NITRATE-N	TOTAL DISSOLVED SOLIDS
SODIUM		

ORGANIC CONSTITUENTS

DISSOLVED ORGANIC CARBON
TOTAL PARTICULATE CARBON
PHENOLIC MATERIAL
OIL & GREASE
ORGANIC SCAN (GC/MS) to identify specific organic compounds

HEAVY METALS

IRON	ARSENIC
ALUMINUM	SELENIUM
MANGANESE	CHROMIUM
COPPER	VANADIUM
ZINC	NICKEL
LEAD	SILVER
MERCURY	ANTIMONY
CADMIUM	BERYLLIUM
COBALT	MOLYBDENUM